Why Should I Vaccinate My Child? A Historical and Scientific Perspective.

An Honors Thesis (HONR 499)

By

Mary Katheryn Reams

Thesis Advisor

Dr. Jennifer Metzler

Ball State University
Muncie, Indiana

May 2020

Expected Date of Graduation

May 2020

Abstract

The anti-vaccination campaign has been around for centuries, although always present, in recent history, there has been an uptick in interest. This interest is based on the spread of misunderstanding and misinformation with social media platforms acting as the catalyst for their campaign. To combat the spread, the promotion of sound scientific literature is vital. This document provides succinct information on all vaccines currently recommended by the Center for Disease Control and Prevention as of Spring 2020. All of the information provided comes from scientific literature and trusted governmental medical authorities. To collect this information, an in-depth literature search was performed in databases including *Web of Science*, *PubMed,* and *JSTOR*; this information was then broken down into a more succinct and readable format. The purpose of this document is to provide credible information to those faced with the decision to vaccinate their child and to provide them with information so they can confidently make that decision.

Acknowledgments

I would like to thank Dr. Jenifer Metzler for her guidance and assistance throughout this project. I would like to thank Dr. John McKillip for helping me foster my interest in the microbial world. I would like to thank my friend, Katie Esarey, for listening to me constantly discuss vaccinations and for answering all my formatting questions. Finally, I would like to thank my fiancé, Lakin Lane, for his constant support and encouragement throughout this project.

Process Analysis Statement

My research on vaccinations is a significant application of academic knowledge and judgment as it drew from my past four years of learning about the microbial world and public health issues. Through this project, I was able to use the research skills I have gained through my time at Ball State University and work on a project that may be similar to what I will do in my future profession. This project also gave me an outlet for future research and create a complication of data about the current vaccination schedule in the United States of America.

The research I primarily engaged in while working on this project was literature research, I read various books on the topic of vaccination both for and against. I read books on both sides of the argument as I felt they would allow me to gain better insight into the mindset and argument style of those who oppose vaccination. While reading anti-vaccination books such as *Evidence of Harm: Mercury in Vaccines and the Autism Epidemic: A Medical Controversy* by David Kirby, I was frustrated with the false information he chose to include as though it was true in his book, this issue made the book difficult for me to read but still beneficial as it did genuinely help me gain insight into the argument style and what if regarded as "fact" in their community. One of the pro-vaccination books I read was *Deadly Choices: How the Anti-Vaccine Movement Threatens Us All* by Paul A. Offit, this text provided great insight into the history of the anti-vaccination movement, and it highlighted many of the leaders in the anti-vaccination movement, this book primarily provided me with the historical context of the anti-vaccination movement as well as providing some scientific information on each vaccine.

Once I began to write this research paper, I started to dig into various databases such as *Web of Science, PubMed*, and *JSTOR* to find scientific literature for each of the vaccines

discussed in the paper. In these databases, I was able to find information on the creation of the vaccine, the effectiveness of the vaccine, the type of vaccine it is, what it is protecting against, how the disease spreads, and some history on it. All of this information was vital to support the underlying argument of this project which was that vaccination is important, necessary, and should not be viewed as optional.

Through researching and working on this project, I learned that I need to break large projects down to manageable sections and set deadlines for myself to ensure I get things done in a timely manner and prevent myself from getting overwhelmed. From this project, I discovered I am able to overcome setbacks and continue to work diligently despite living through a pandemic and in a time where every day something new changes. I also learned that I can be an effective researcher and I am able to successfully apply the knowledge I have gained from my time as an undergraduate student.

I believe this project is important because we are now facing a global health crisis because of the current anti-vaccination movement, World Health Organization (WHO) has moved vaccine hesitancy to the top ten threats to global health. The information presented in this project allowed me to develop a succinct and easily understood paper that explains the purpose and background of each vaccination. This project allowed me to build on to the public health field since my goal was for this project to help hesitant new parents make an informed decision on their child's health. A large part of public health is helping others to make an informed decision, but also informing others of how their actions affect the overall health of the world. My main goal for my project is that I want others who read it to feel informed and comfortable with vaccinations, with the hope that they will take this new knowledge they have acquired and share

it with others. Ultimately, I want this project to make a positive impact on global health, as the more vaccinated people in the world the healthier it will be.

Introduction

The concept of vaccination has been debated ever since its inception in 1776 when Edward Jenner developed the smallpox vaccine. Although vaccine use can be traced back to Asia in the 700 BCE, where it was known as variolation rather than vaccination (Allen, 2008, p.27). Why has vaccination always been such a polarizing topic? Could it be a lack of proper information, lack of proper education, the megaphone the internet acts as for sharing one's opinion, or could it be the overwhelming nature of caring for a child and striving to do the best for them? It is easy to see the vaccine debate is multifaceted, and the reasoning used against vaccination is not easily debunked. The pro-vaccination vs anti-vaccination debate is rooted not necessarily in facts and scientific data but primarily in emotion. Those in support of vaccinations attempt to use factual information and use research to support their argument but eventually, they can become worn down and resort to Ad hominem attacks. Those in the anti-vaccination party also use facts and scientific information, but often it is not "good" science or information is pulled from scientific articles out of context, and as the argument continues many resort to Ad hominem attacks as well. While it is necessary to have civil discussions about difficult topics, I feel it is most important to become as well informed as possible when tasked with making an important and life-altering decision for themselves or often for their children.

The vaccination debate is often amplified and muddled through the use of social media and the internet in general. While the internet brings us closer and more connected than ever, it also allows for rampant sharing of false information, which depending on what is shared can be harmful to oneself and others or even deadly. So, to help mitigate this, we need to promote

quality, fact-checked information on the internet and in general life. I have chosen to create this paper as a way to help promote factual information, in an easy to read format. With each of the vaccines I discuss, I will explain information about it from trusted sources and keep it to a reasonable length adding to its readability.

In hopes of helping those interested in vaccinations, as well as helping those in the position of choosing to vaccinate their child or not, I have gone through the current recommended vaccine schedule used in the United States of America and explained each vaccine. Below one can find each vaccine, how many doses are needed when to receive said doses, the type of vaccine it is, what it is protecting against, how the disease spreads, how effective the vaccine is, what life was like before its introduction, and a little history on its creation. With this information, I hope guardians can make an informed decision and feel comfortable with that decision. Ultimately, I feel that being fully and properly vaccinated is of the utmost importance for protecting yourself along with family, friends, and the general population.

Hepatitis B (Recombivax HB, Engerix-B)

The first vaccine an infant receives is hepatitis B, this vaccination is given within the first 24 hours of life (Dapaah-Siakwan, Gunasekaran, & Schutzman, 2016). The hepatitis B vaccine is given in a series of 3 doses, first within a day after birth, second when the infant is one or two months old, and third dose is given between six months to eighteen months (The Center for Disease Control and Prevention [CDC], 2020). The current hepatitis vaccine has proved to provide long term immunity when all three doses are received, a study of 1352 participants found that 74.5% had anti-HBs antibodies at detectable levels in their blood 17-20 years after their last

vaccine (Zhao, et al., 2019). So, why does an infant need to be vaccinated against a disease transferred through unprotected sexual contact and drug use (Offit, 2015, p. 63-68). Hepatitis B can be given to the infant while in utero from the mother's blood supply, as hepatitis B can be spread through blood, semen, and other bodily fluids (CDC, 2020). Hepatitis B is one of the five types of viral hepatitis, hepatitis causes an inflammation of the liver. Hepatitis B can be seen as an acute or chronic infection, with symptoms such as abdominal pain, fever, joint pain, dark urine, jaundice, weakness, fatigue, nausea and vomiting (Mayo Clinic, 2017).

If an infant is infected with hepatitis B, they can face a lifetime of medical issues such as a chronic hepatitis B infection which leads to an increased risk for developing liver cancer, cirrhosis, or liver failure (Mayo Clinic, 2017). One can be vaccinated against hepatitis B to build immunity but if one is not vaccinated against hepatitis B there is no cure for the conditions and must take precautions to prevent spreading the virus to others (CDC, 2020). For the hepatitis B vaccine to be effective 95%, with a range of 80-100%, of people need to be vaccinated against it. Currently in the United States of America, the vaccination rate is 91.4% (Meireles, Marinho, & Van Damme, 2015)). In 1963 the Australian antigen was discovered by physician and geneticist Baruch Blumberg, this "antigen" was a protein found in the blood of an Australian aborigine, this protein was determined to be the same as the surface proteins on the hepatitis B virus (Blumberg, Alter, & Visnish,1965). The protein was used as a marker to determine if one had been previously infected or was currently infected with hepatitis B and named the Australian antigen by Dr. Blumberg (Blumberg, Alter, & Visnish,1965). In 1968 virologist Alfred Prince discovered the viral protein (Howard & Zuckerman, 1979), this viral protein led to the creation of the vaccine by microbiologist and vaccinologist Maurice Hilleman, who also developed the first iteration of the vaccine (Offit, 2007). That version was taken out of production in 1986 and

replaced when Pablo Valenzuela discovered the antigen could be produced using a yeast strain, this version of the hepatitis B vaccine is what we still use today (Fisher, 1986).

The world without the hepatitis B vaccine was once ravaged by its symptoms, the groups that had the highest incidence in the 1980s would be gay men, those who use injection drugs, sex-workers, the children of women who tested positive for hepatitis B, and health care workers. This continued even in to the 1990s with roughly 1.5 million people transmitting hepatitis B as many were asymptomatic (Conis, 2011). Through the Vaccines for Children program, which was introduced in 1993 in the United States of America, allowing for children to be vaccinated saving nearly 936,000 from this preventable disease and preventing potentially 322 million illnesses (Conis, 2011). Today 98% of infants achieve full immunity to hepatitis B and the rate is down to 1,000 new cases of hepatitis B each year in infants, the goal is to get it down to 0 but to achieve that we will need to continue combating the opioid epidemic in the United States (American Academy of Pediatricians [AAP], 2017).

DTaP (Daptacel, Infanrix) **/ Tdap** (Boostrix)

What does DTaP stand for? The D stands for diphtheria, the T stands for tetanus, and the aP stands for pertussis; a child receives the DTaP vaccine at 2 months, 4 months, 6 months, 15-18 months, and 4-6 years (CDC, 2020). Diphtheria is a bacterial infection that affects one's mucous membranes, such as the throat and nasal passages, it can cause difficulty breathing, heart failure, kidney damage, paralysis or even death (Hadfield, Mcevoy, Polotsky, Tzinserling, & Yakovlev, 2000). Tetanus is caused by a bacterial toxin that targets the nervous system (motor neurons), causing muscle contractions specifically in the neck and jaw, these muscle contractions can impair breathing as well; the bacteria that produce the tetanus toxin can be found in soil,

dust, and animal feces (Rosenblatt, et al., 2005). Pertussis is commonly referred to as whooping cough, it is a bacterial infection that affects the upper respiratory tract, it is highly contagious and causes one to have uncontrollable violent coughing this makes it difficult for one to breath often leading to pneumonia, rib fractures, brain damage, and possibly death (Von König, Halperin, Riffelmann, & Guiso, 2002). If an infant contracts any of these illnesses, they have a high likelihood of dying as each has an effect on their ability to breath. In the United States of America diphtheria is very rare due to proper vaccination, only two cases between 2004-2015, but prior to the vaccine's introduction the mortality rate in 1920 was 8.9% of the 147,000 cases (Dauer, 1940). As for tetanus the 56,743 deaths attributed to tetanus in 2015 35.1% of those where infants (Kyu, et al., 2017), and pertussis has an infant mortality rate of 13.1%, per one million births (Haberling, Holman, Paddock, & Murphy, 2009).

Before the DTaP vaccine we use today came into existence, the vaccine was broken up into three parts. In the 1920s a whole cell pertussis vaccine was used for adolescents and adults but not for children (Lapin, 1943) in the 1940s pertussis was added to the diphtheria and tetanus vaccine and was called the DTP vaccine, leading to a large drop in childhood pertussis cases (Pertussis Vaccination, 1997). The DTaP vaccine was introduced in 1991 by introducing acellular pertussis rather than whole cell pertussis since they discovered the antigens were needed but not the whole cell, this lowered the chance of side effects and the DTaP vaccine replaced all DTP vaccines by 1997 (Pertussis Vaccination, 1992). The DTap Vaccine has an effectiveness of 80% within the first year, within 1-3 years it is 84%, within 4-7 years it lowers to 62%, and after 8 years it lowers again to 41% (Schwartz, et al., 2016). So, for those between 11-18 years a booster is required, this began in 2005, this booster allows for the effectiveness to

be raised back up to 75.3% although this effectiveness wanes over the years like the original vaccine, the current solution is receiving a booster every ten years (Koepke, 2014).

While this vaccine requires multiple doses to achieve immunity, it is of extreme importance that we continue to vaccinate against diphtheria, tetanus, and pertussis, especially with pertussis as it is a highly communicable disease. In the United States of America there was a pertussis outbreak in 2012 resulting in 48,277 cases, these types of outbreaks put everyone at risk especially infants so it is important they receive all of the vaccine doses to help mitigate the spread of pertussis along with diphtheria, tetanus although these have been successfully controlled in the recent past (Worby, Kenyon, Lynfield, Lipsitch, & Goldstein, 2015).

IVP (Ipol)

What does IVP stand for? Inactivated Poliovirus Vaccine, this is the polio vaccine used in the United States of America, there is a live oral vaccine option still used in developing nations today (World Health Organization [WHO], 2016). The Inactivated Poliovirus vaccine is given in 4 doses at 2 months old, 4 months old, between 6-18 months old, and between 4-6 years old (CDC, 2020). Polio is a viral illness transmitted through direct contact with an infected person, much less common today is contraction through water or food although in developing nations it is passed through water still as the polio virus can survive for weeks in feces (Oshinsky, 2005, p. 282-283). There are two forms of polio, non-paralytic and paralytic polio, signs of nonparalytic polio include fever, headache, vomiting fatigue, stiffness or pain in the back, neck, arm, and/or legs (Bruno, 2000). Signs of paralytic polio are the same as nonparalytic polio, but one may experience loss of reflexes, severe muscle weakness and aching, and flaccid paralysis (Bruno, 2000). It is also important to note that poliovirus has three different serotypes, a serotype is a

variation distinct enough from the original species, there is poliovirus type 1, type 2, and type 3 each has a different capsid protein, but all forms present the same symptoms (McBean, et al., 1988).

The first polio vaccine was created in 1950 by virologist and immunologist Hilary Koprowski, this was an oral version with an attenuated virus meaning the virus was still live, but it was weakened to wear it could not cause an infection (Koprowski, 2011). This was an extremely important scientific breakthrough, but it could not be used yet as it was still in the research phase, while in this research phase there was an increase in polio cases in the United States of America from 25,000 annually to 58,000 in 1952 and the death toll rose to 3,200 or 5.5% of cases (Ochmann & Roser, 2017). In 1952 Jonas Salk developed the first successful polio vaccine and by 1954 school children were beginning to receive the vaccination, and in 1955 all American children were being vaccinated against polio (Offit, 2007). Salk's vaccine was an inactivated vaccine, it was found to be 65% effective against poliovirus one, 90% effective against poliovirus two, and 94% effective against bulbar polio (Smith, 1991). Things changed in the 1960s when Albert Sabin successfully developed an attenuated version of the polio vaccine, this oral vaccine had all three types of polio and in 1961 replaced Salk's vaccine (Pearce, 2004).

Sabin's oral polio vaccine remained in use until the late 1980s when a new version of inactivated vaccine was developed, this allowed for individuals to develop antibodies and after three doses one becomes 99% immune to all three types of polio virus (Dawson, 2004). In the United States of America polio was declared eliminated in 1994, there is still a change of contracting wild poliovirus or a mutated strain of it, along with there being countries in the Middle East like Pakistan and Afghanistan, and Nigeria in Africa are still dealing with polio cases (Hagan, 2015). So, with our world continuing to shrink through travel, we still need to be

vaccinated against polio even if it was eradicated in the United States of America 26 years ago (Thompson, 2013). The task of eradication has been taken up by the World Health Organization, as their next target for complete disease eradication through vaccination, they have targeted polio because it only affects humans and once vaccinated one gains lifelong immunity (WHO, 2015).

Pneumococcal (PCV13, Prevnar 13)

The Pneumococcal conjugate vaccine is given in 4 doses at 2 months, 4 months, 6 months, and between 12 and 15 months (CDC, 2020). The current pneumococcal conjugate vaccine, PCV13, protects against the 13 different types of pneumococcal bacterial infections, these infections can result in pneumonia, bacterial meningitis, or septicemia better known as blood infections (Broome, Facklam, & Fraser, 1980). The pneumococcal vaccine can also be referred to as the pneumonia vaccine as that is the most common outcome from *Streptococcus pneumoniae* infections, while this vaccine protects against bacterial infection it is important to note that since the 1990s there has been an increase in antibiotic resistant pneumococcal infections, 16.4% of all cases have resistance to at least one antibiotic class (Breiman, Butler, Tenover, Elliott, & Facklam, 1994). With this increase in antibiotic resistance the need for a properly vaccinated society is made much higher as early developed immunity from vaccinations is the most effective form of protection, especially when children are much more likely than adults to be infected by one of these antibiotic resistant strains (Breiman, Butler, Tenover, Elliott, & Facklam, 1994). This vaccine has been found to have 70% efficacy against invasive pneumococcal disease (IPD) after one dose and after four doses it is raised to 94.5% (Miller, Andrews, Waight, Slack, & George, 2011).

Through the United States of America's anti-diphtheria campaign in the 1920s many vaccines and sera for other diseases were created, one of those diseases being pneumococcal but the serum treatment was unsuccessful against pneumonia as it was made from type 1 and 2 pneumococcal samples, and physicians were unaware of the many types of pneumococcal strains (Allen, 2008, p. 129). Since it was ineffective it was put on the backburner until 1977 when a pneumococcal vaccine that created immunity against14 different strains was developed, this was used until 1983 when PPSV23 a polysaccharide vaccine against 23 different strains was created this was taken off the market when it was discovered that the PPSV23 vaccine produced immunity in adults and older children but it did not consistently produced immunity in those under 2 years of age (Pilishvili, & Bennet, 2015). In 2000, the PCV7 conjugate vaccine was introduced for use in children, this vaccine protected against seven strains of pneumococcal infections with an efficacy of 82-97% against IPD and 90% against clinically diagnosed pneumonia (Oosterhuis-Kafeja, Beutels, & Van Damme, 2007). This PCV7 vaccine was then expanded in 2010 to PCV13, which is what we use currently, it protects against the most severe strains that cause childhood pneumococcal infections primarily bacterial meningitis (Greenberg, Givon-Lavi, Ben-Shimol, Ziv, & Dagan, 2015).

Prior to the introduction of a pneumococcal vaccine, a study done in South Africa shows that before the vaccine in 2012 there were 107,600 (upwards of 140,000) cases of severe hospitalized pneumococcal disease, after the introduction of PCV13 it dropped to 41,800 cases and the child mortality rate went from 1,900 per 100,000 to 61, 100,000 (von Mollendorf, et al., 2017). The United States of America saw a similar outcome following the addition of the pneumococcal vaccine to the childhood immunization schedule, thus supporting the efficacy of this vaccine and its need in our society (Tsai, Griffin, Nuorti, Grijalva, 2008).

Hib (PedvaxHIB)

Haemophilus influenzae type b vaccine is given in 3 doses at 2 months, 4 months, and a booster at 12-15 months (CDC, 2020). The *Haemophilus influenzae* type B vaccine is a conjugate vaccine protecting against one of the three main causes for bacterial meningitis in children under five years old (Allen, 2008, p. 307). A *Haemophilus influenzae* type B infection can also cause pneumonia and epiglottitis in children, it can also cause inflammatory infection of the face, mouth, blood, joints, heart, and bones (WHO, 2014). *Haemophilus influenzae* type B is spread through respiratory droplets, as in coughing and sneezing, it can also be spread through asymptomatic carriers as the *Haemophilus influenzae* bacteria can reside in the throat and nose (Auranen, Ranata, Takala, & Arjas, 1996). The *Haemophilus influenzae* type B conjugate vaccine is universally effective against all forms of *Haemophilus influenzae* type B diseases but it is not effective against any other type of *Haemophilus influenzae* although those infections are uncommon in comparison to type B (Allen, 2008, p.328). The efficacy of the Hib vaccine is 84% against invasive *Haemophilus influenzae* type b disease, 75% effective against bacterial meningitis, and 69% effective against pneumonia; these values came from a meta-analysis of eight randomized vaccine trials (Obonyo, & Lau, 2006).

The Hib vaccine came at a time when this organism was the leading cause of meningitis for children under 5 years of age, it was licensed in the US in December of 1987 that version was approved for children 18 months and older and in October of 1990 the second iteration of the Hib vaccine was approved for infants 2 months and older (Adams, 1993). After the addition of this vaccine, incidence of *Haemophilus influenzae* type 2 in children under 5 years of age

decreased from 37 per 100,000 people in 1989 to 11per 100,000 people in 1991 this was a 71% case decrease in 2 years (Adams, 1993). Going back further from 1985 to 1991 an 82% case decrease can be seen, over all the addition of this childhood vaccine is estimated to prevent 10,000-16,000 cases of childhood Hib in 1991 alone (Adams, 1993). More recent data shows the incidence is down to 1 per 100,000 cases in the United States of America, but globally the burden has not been eased (Watt, et al., 2009). There are 8 to 13 million Hib related illnesses worldwide, with it causing 371,000 deaths annually in children between 1 month and 5 years of age (Watt, et al., 2009). With Hib causing so many childhood deaths it is clear to see that from the vaccine's success in the United States of America it is of extreme importance to get this vaccination to children in developing nations to prevent their unnecessary deaths. It should be noted that non-for-profits are working to make this a reality such as the Bill and Melinda Gates foundation, in July of 2003 4 million children received Hib vaccines and in Gambia through this vaccine initiative they were able to wipe out Hib disease by 2005, so it is possible to eventually eliminate but until then it is of utmost importance to continue vaccinating against Hib (Allen, 2008).

Rotavirus (Rotarix Rv1)

The rotavirus vaccine is given in 2 doses at 2 and 4 months of age, and is given orally (CDC, 2020). Rotavirus is prevalent in infants and children, and causes gastrointestinal distress such as diarrhea, vomiting, abdominal pain, and fever; often leading to dehydration and hospitalization (Rarashar, Bresse, Gentsch, & Glass, 1998). Rotavirus spreads through air, food, fomites, skin, and water, with water being the largest contributor to rotavirus infections in the developing world (Ansari, Springthorpe, & Sattar, 1991). In the developing countries rotavirus

infections make up for 6% of all diarrheal incidences and the cause of 20% of diarrhea-associated deaths of children under 5 years of age; while a large issue in developing countries rotavirus infection is still an issue for children in developed nations (Ansari, Springthorpe, & Sattar, 1991). Rotavirus infections peak at different times depending on the location such as in the tropics it is present all year because of the humid air, while temperate regions see their peak in cool dry weather like late fall (Ansari, Springthorpe, & Sattar, 1991).

The rotavirus vaccine was added to the childhood immunization schedule in 1998, it remained in use until 1999 when it was taken off the market due to intussusception also known as bowel obstruction in infants as a possible side effect from the vaccine (Allen, 2008, p. 319). The rotavirus vaccine was added back to the childhood immunization schedule after further testing, so in 2008 Rotarix became the new and safer version (Offit, 2015). The rotavirus vaccine is a monovalent live attenuated vaccine with the attenuated virus identified in human subjects (O'Ryan, Lucero, & Linhares, 2011). The rotavirus vaccine protects against gastroenteritis, an inflation of the intestinal lining, caused by the G1, G3, G4, and G9 types (O'Ryan, Lucero, & Linhares, 2011).

In 1973 rotavirus was discovered and during that time period it has been estimated that nearly every child in the world would get at least one rotavirus infection before the age of 5 (Allen, 2008). In the United States of America alone there were nearly half a million pediatrician visits a year and 50,000 hospitalizations from dehydration caused by a rotavirus infection (Allen, 2008). While in the United States of America death from rotavirus was uncommon, in developing nations rotavirus was responsible for the death of 870,000 children yearly (Allen, 2008). These figures highlighted the seriousness of rotavirus and the need for a vaccine to prevent these infections, the current rotavirus vaccine has an efficacy of 90.4% against

gastroenteritis caused by types G1-G4 and G9, this vaccine lowered hospital admission rates due to rotavirus by 96% (Vesikari, et al., 2007). With a vaccine this effective and easily administered orally it is literally a life safer for children in developing nations in Africa, Asia where health care systems are not well developed or easily accessible.

Measles, Mumps, and Rubella – (M-M-R II)

The Measles, Mumps, and Rubella, also known as German Measles, (MMR) vaccine is given in two doses at 12-15 months, and at 4 to 6 years; the MMR vaccine is a live attenuated immunization (CDC, 2020). The MMR vaccine protects against three different infections, measles is a viral infection, caused by the measles virus from the *Morbillivirus* genus, that begins in the respiratory system with symptoms such as a wide spread rash, cough, runny nose, fever, sore throat, white spots inside the mouth and red eyes, these symptoms developed with in 10-12 days of exposure (Naim, 2015). Since measles begins in the respiratory tract, it is spread through coughing and sneezing allowing it to remain in the air for up to two hours (Naim, 2015).

The MMR vaccine also protects against the mumps which is a viral infection caused by a paramyxovirus from the Rubulavirus family (Mumps, 2019). Symptoms of the mumps incudes swollen salivary glands, pain while swallowing and chewing, headache, fatigue, fever, muscle aches, and loss of appetite; it spreads through saliva so one can contract it by sharing utensils as well as respiratory droplets from coughing and sneezing (Mumps, 2019).

Rubella or German measles is the final disease that the MMR vaccine offers protection against. Rubella is a viral infection caused by the *Rubivirus* from the Togaviridae family (Parkman, 1996). Symptoms of rubella include inflamed red eyes, enlarged lymph nodes at the neck and behind the ears, aching joints, a pink rash on the body, and a mild fever below 120ºF

(De Santis, Cavaliere, Straface, & Caruso, 2006). Rubella can be spread by direct contact with an infected person's mucus as well as through sneezing and coughing, also pregnant women can spread rubella to their fetus through the placenta (De Santis, Cavaliere, Straface, & Caruso, 2006). If the mother contracts rubella during pregnancy some of the risks include miscarriage, still birth, or Congenital Rubella Syndrome (CRS) in the fetus (CDC, 2017). The side effects of a CRS infection include live and spleen damage, deafness, low birth weight, cataracts, heart defects, skin rash at birth, and intellectual disabilities; there is no cure for CRS only preventive measures such as proper vaccination (CDC, 2017).

The M-M-R II vaccine is given in two doses, after on dose the vaccine is 93% effective against measles, 78% effective against mumps, and 97% effective against rubella. (CDC, 2019). After the second dose the vaccine is 97% effective against measles, 88% against mumps, and remains 97% effective against rubella (CDC, 2019). The MMR vaccine was developed by Maurice Hilleman and licensed for use by Merck in 1971, prior to this combination vaccine stand-alone vaccines for measles, mumps, and rubella were used (Allen, 2008, p.240).

For the MMR vaccine to achieve proper herd immunity 95% of individuals need to be vaccinated against it, particularly children under 2 years of age need at least one dose and their second dose or booster before 5 years of age (Cockman, Dawson, Mathur, & Hull, 2011). A Finnish survey on their national vaccination program, which in 1982 began requiring the MMR vaccine, found that prior to the requirement the incidence of measles was 105 cases per 100,000 people, for mumps it was 43 cases per 100,000 people, and for rubella it was 64 cases per 100,000 people (Davidkin, Kontio, Paunio, & Peltola, 2014). Following their vaccination program by 1995 the incidence rates had declined to 0.1 cases per 100,000 people for measles, mumps, and rubella (Davidkin, Kontio, Paunio, & Peltola, 2014). This high compliance with

vaccines has allowed Finland to essentially eliminate measles, mumps and rubella from their country, although they do plan to continue surveillance to ensure MMR disease remains eliminated (Davidkin, Kontio, Paunio, & Peltola, 2014). As of 2017, 91.5% of children in the United States of America received at least one dose of their MMR vaccine, this percentage has remained in the 90s since 1998 (CDC, 2017). While 95% is needed to ensure proper herd immunity, I believe that the United States of America could reach that percentage within the foreseeable future preventing many children from becoming needlessly infected.

Hepatitis A – (Havrix)

The hepatitis A vaccine is given in two doses one at 12 months followed by the second dose 6-12 months later, the hepatitis A vaccine is an inactivated vaccine using a killed virus (CDC, 2020). *Hepatovirus A* (HAV), the virus that causes hepatitis A liver disease, it does not cause chronic liver disease such as hepatitis B and C do (WHO, 2019). Hepatitis A infections can cause fulminant hepatitis and acute liver failure, which is fatal (WHO, 2019). Symptoms of hepatitis A infection include jaundice, abdominal discomfort, dark urine, nausea, loss of appetite, diarrhea, and fever (WHO, 2019). Hepatitis A virus is spread through food or water contaminated with fecal matter from an infected individual, often with outbreaks occurring in areas with unsafe water and food, poor sanitation, and poor hygiene such as handwashing (WHO, 2019).

Introduced in 1992, Harvix was one of the first effective vaccines against hepatitis A, and provided lifelong protection (Van Herck, & Van Damme, 2005). A study conducted by the CDC and the National Notifiable Disease Surveillance System (NNDSS) found that in the United States of America there was 31,522 cases of acute hepatitis A infections and an estimated

3743,000 total infections in 1990; as of 2010, 11 years after the hepatitis A vaccine was added to the vaccine schedule, there was 1,670 cases of acute hepatitis A infection and an estimated 17,000 total cases (2013). While the United States of America has lowered the amount of hepatitis A infections in the past decade, outbreaks continued to occur between 1994 and 2004 there were 256 outbreaks in the United States of America equaling 23 each year (Craig, Watson, Zink, Davis, Yu, & Schaffner, 2007). The infection rate worldwide for contracting hepatitis A directly related to those without access to safe drinking water and where they fall on the socio-economic scale; it has been seen that those in countries higher on the scale have low levels of hepatitis A infections while those on the low end of the scale often have high incidence of hepatitis A infections (Jefferies, Rauff, Rashid, Lam, &Rafiq, 2018). Yearly, 1.5 million cases of hepatitis A infections are reported but it is assumed that the actual case count is much higher, since the highest incidences of cases can be found in primarily poor areas with little access to medical care such as Sub-Saharan Africa (Jefferies, Rauff, Rashid, Lam, &Rafiq, 2018). With this knowledge, I feel that it is extremely important to increase access to this vaccine rather than having children gain immunity to hepatitis A post infection, as many of the symptoms associated with this infection can be deadly to children.

Varicella – (Varivax)

The Varicella or Chickenpox vaccine is given in two doses, one at 12 to 15 months and one between 4 to 6 years of age; Varivax is a live attenuated vaccine (CDC, 2020). Varicella is a highly contagious infection caused by the *varicella-zoster* virus, symptoms include a blister-like, itchy rash first on the chest, back and face and then spreads to the whole body (Gershon, 2006, p.92). Chickenpox is transmitted by coming in contact with an infect persons saliva or mucus or

touching the blistered rash of an infected person (Gershon, 2006, p.92). In the first half of the 1990s, around 4 million people got chickenpox each year resulting in 10,000-13,000 hospitalizations and around 100 deaths (Allen, 2008, p.312). The chickenpox vaccine was licensed in the United States of America in 1995 and by 1999 60% of toddlers were receiving the vaccine nationwide and only 1 in 10 children got chickenpox (Allen, 2008, p.315). By 2010 chickenpox infections were down by 79% throughout the country, hospitalizations were down by 93%, and deaths were down by 87% (CDC, 2018).

The efficacy of the varicella vaccine after one dose is 84.5% effective against all varicella and it is 100% effective against severe varicella infections (Seward, Marin, & Vázquez, 2008). Two doses of the varicella vaccine are encouraged to create stronger immunity against varicella infections, after the second dose the efficacy is raised to 95% against all varicella and remains 100% effective against severe infections (Seward, Marin, & Vázquez, 2008). In countries without access to the chickenpox vaccine they see a spike in additional infections and complications such as *varicella-zoster* virus induced pneumonitis, encephalitis, and group A *streptococcal* infections, as well as, dormant varicella-zoster virus lingering in the neural ganglia, the structures containing cell bodies of neurons, leading for reactivation later in life often seen as shingles in the elderly adults (WHO, 2014). This highlights the need to expand access to this vaccine to those living in countries with high varicella infections but low vaccination rates.

Prior to the invention of the chickenpox vaccine, chickenpox was often seen as a childhood rite of passage in regard to illness, many parents remembered it as a benign illness resulting in a week or so of discomfort (Allen, 2008, p.313). From the statistics shared above one can see that chickenpox is not a benign illness, it is an illness that can lead to complications,

hospitalizations and death in some cases. Since so many parents did not take chickenpox as seriously as they should have, a major turning point in promoting this vaccine was that by the mid 90s many women with children worked and could not afford to stay home for a week or more with a sick child (Allen, 2008, p.313). With this complication, vaccine rates for the chickenpox vaccine and many others began to climb, and in turn allowed for a healthier society. It should also be noted that chickenpox is less severe for children, but for immune-compromised adults and the elderly it causes shingles which can lead to permeant nerve damage (CDC, 2018).

Meningococcal serogroup A, C, W-135, Y – (Menactra, Menveo)

The meningococcal serogroup ACWY vaccine is given in two doses first one between 11-12 years of age and the second at 16 years of age (CDC, 2020). The meningococcal ACWY vaccine is a conjugate vaccine, it offers protection against *Neisseria meningitidis* which is the bacteria that causes a severe type of meningitis, the swelling of the tissue around the brain and spinal cord, as well as, sepsis which is a blood stream infection (Bermal, et al., 2011). Symptoms of bacterial meningitis include stiff neck, headache, confusion, high fever, exhaustion, a rash with a purple tinge, and vomiting (Bermal, et al., 2011). Meningococcal disease spreads primarily through coming in contact with the saliva or mucus of an infected person, or by being in close contact for extended amounts of time with an infected person such as kissing and sharing utensils (Bermal, et al., 2011).

The meningococcal vaccine was first developed in the 1970s as a polysaccharide vaccine, this version of the vaccine was not effective in creating immunity in children, but it was successful in developing immunity in adults (Noya, McCormack, Reynolds, Neame, & Oster, 1970). Currently a conjugate vaccine is used in the United States of America providing

protection against four of the main agents that cause meningococcal disease, this vaccine, Menactra, was licensed in 2005 and approved for use in those 9 months to 55 years of age (FDA, 2010). The other meningococcal conjugate vaccine is Menveo was licensed in 2010 and approved for use in those 11 to 55 years of age (FDA, 2010).

The efficacy of the meningococcal disease vaccine is very high after receiving the full course. The vaccine is 83% effective against serotype A, 98% effective against serotype C, 99% effective against serotype W-135, and 98% effective against serotype Y (Snape, et al., 2008). Meningococcal disease has a high fatality, reaching 50% when left untreated, and it is highly contagious especially since it can present asymptomatically (WHO, 2018). Meningococcal disease effects every nation but the developing world has the highest incidence of infections, with as many as 30,000 cases reported each year in sub-Saharan Africa (WHO, 2018). It should be noted that sub-Sharan Africa is mostly affected by serotype A infections (Harrison, Trotter, & Ramsay, 2009). Most meningococcal infections in the United States of America are serotype C, B, and Y with W-135 on an uptick (Harrison, Trotter, & Ramsay, 2009). The incidence rate of infection in the United States of America is low due to a high vaccination rate of 86%, but still 600-1,000 infections occur each year with a 10-15% fatality rate (Harrison, Trotter, & Ramsay, 2009). These values highlight the deadliness of meningococcal infections and why continued vaccination against meningococcal serogroup A, C, W-135, and Y is vital to the health and safety of adolescents and adults.

Human Papilloma Vaccine – (Gardasil 9)

The human papillomavirus (HPV) vaccine is given in two doses, the first dose is given between 11 and 12 years of age and the second is given 6 to 12 months after the first dose; a

third dose is needed if the first dose is given outside of the recommend age window (CDC, 2020). The HPV vaccine (Gardasil 9) is a recombinant vaccine made from purified virus-like particles from the proteins of nine HPV types: 6, 11, 16, 18, 31, 33, 45, 52, and 58 (Petrosky, et al., 2015). Prior to the licensing of the nine valent HPV vaccine (Gardasil 9) in 2015, a quadrivalent HPV vaccine (Gardasil) was used until 2014, it was only replaced because the new vaccine offered more protection against more strains of HPV (Petrosky, et al., 2015).

Human papillomavirus is one of the most common STIs, it is transmitted through close skin-to-skin contact as well as having oral, vaginal, or anal sex with an infected person (Dunne, Unger, Sternberg, McQuillan, Swan, Patel, & Markowitz, 2007). In females from the United States of America 14 to 59 years of age have an HPV infection rate of 26.8% (Dunne, Unger, Sternberg, McQuillan, Swan, Patel, & Markowitz, 2007). For males from the United States of America 18 to 70 years of age have an HPV infection rate of 20% to 34% (Smith, Gilbert, Melendy, Rana, & Pimenta, 2011). Symptoms of an HPV infection include warts or growths on the skin or mucous membrane often genital warts, in some cases lesions can grow on the tongue, tonsils, throat, and nose leading to difficulty breathing (Stone, 1995). A main concern of an HPV infection is that certain strains can cause cervical cancer, as well as, genital, anal, mouth or upper respiratory tract cancers (Stone, 1995).

It is important to receive the HPV vaccine between ages 9 to 13, as this is often before one becomes sexually active (Viens, et al., 2016). One way to track HPV infection rates is to look at cervical cancer rates, as nearly all cervical cancer is caused by an HPV infection (Viens, et al., 2016). Between 2008 and 2012 there were 38,793 HPV-associated cancered diagnosed annually, the gender breakdown was 23,000 female cases and 15,793 male cases (Viens, et al., 2016). Within these cancer diagnoses upwards of 30,000 were caused by HPV and 28,000 of

those cases were from strains found within the 9-valent HPV vaccine, thus being preventable (Viens, et al., 2016). HPV infections can develop into cancer as it often presents asymptotically, if one has been infected with one of the 13 oncogenic (cancer producing) HPV types this asymptotic feature allows for this infection to progress unchecked sometimes for years (Viens, et al., 2016).

From this one can see the need for the HPV vaccine as it provides protection not only against an STI but also against the onset of cancer later in life. Once vaccinated one can know they are protected from the short-term inconvenience of a "benign" HPV infection, as well as, the turmoil cancer places on the patient, their family, and their future. Like many of the other vaccines mentioned in this paper it can be seen that vaccines not only offer physical protection but also mental protection as they give peace of mind to parents and to the one vaccinated even if it is not abundantly clear in the moment.

Conclusion

The importance of vaccination is often undervalued because the diseases these vaccinations offer protection against are often forgotten about or misremembered since they are not prevalent in our society. An example of misremembering a childhood illness would be chickenpox, many adults remembered it as a benign illness when in reality it can be benign for some but there is a real chance for serious complications to arise (Allen, 2008, p. 313). It is important for members of society, especially for those in the United States of America, to be reminded of the severity these childhood illnesses have. In an effort to help convey the

seriousness of these diseases, this document includes many of the symptoms, side effects and mortality of them.

The main goal of this document was to help inform and educate those faced with the decision of vaccinating or not vaccinating their child. This document allows for the presentation of knowledge without the fear of misrepresentation or misinformation that is often found on the internet and social media sites. By being presented with this factual, scientifically supported information one should be able to feel confident in the recommendations made by these medical professionals and scientists, as one can see that at the root of all this research is the goal of making the world healthier and safer overall. With this information in hand, one can confidently decide to trust science and give their child the best chance at a healthy life.

Documentation of Sources:

Adams, W. G., Deaver, K. A., Cochi, S. L., Plikaytis, B. D., Zell, E. R., Broome, C. V., ... & Stull, T. (1993). Decline of childhood Haemophilus influenzae type b (Hib) disease in the Hib vaccine era. Jama, 269(2), 221-226.

Adolescent Health, 48(6), 540–552. Doi: 10.1016/j.jadohealth.2011.03.010

Allen, A. (2008). *Vaccine: the controversial story of medicines greatest lifesaver*. New York: W.W. Norton.

American Academy of Pediatricians. (2017, August 28). AAP Recommends That Infants Receive First Hepatitis B Dose Within 24 Hours of Birth. Retrieved from https://www.aap.org/en-us/about-the-aap/aap-press-room/Pages/AAP-Recommends-That-Infants-Receive-First-Hepatitis-B-Dose-Within-24-Hours-of-Birth.aspx

Ansari, S. A., Springthorpe, V. S., & Sattar, S. A. (1991). Survival and vehicular spread of human rotaviruses: possible relation to seasonality of outbreaks. Reviews of infectious diseases, 13(3), 448-461.

Auranen, K., Ranta, J., Takala, A. K., & Arjas, E. (1996). A statistical model of transmission of Hib bacteria in a family. Statistics in medicine, 15(20), 2235-2252.

Bermal, N., Huang, L. M., Dubey, A. P., Jain, H., Bavdekar, A., Lin, T. Y., ... & Miller, J. M. (2011). Safety and immunogenicity of a tetravalent meningococcal serogroups A, C, W-135 and Y conjugate vaccine in adolescents and adults. Human vaccines, 7(2), 239-247.

Blumberg, B.S., Alter, H.J., Visnich, S. (February 1965). "A "New" Antigen in Leukemia Sera".
Breiman, R. F., Butler, J. C., Tenover, F. C., Elliott, J. A., & Facklam, R. R. (1994). Emergence of drug-resistant pneumococcal infections in the United States. Jama, 271(23), 1831-1835.

Broome, C. V., Facklam, R. R., & Fraser, D. W. (1980). Pneumococcal disease after pneumococcal vaccination: an alternative method to estimate the efficacy of pneumococcal vaccine. New England Journal of Medicine, 303(10), 549-552.

Bruno, R. L. (2000). Paralytic vs." nonparalytic" polio: distinction without a difference? American journal of physical medicine & rehabilitation, 79(1), 4-12.

Center for Disease Control and Prevention. (2017, September 15). Rubella. Retrieved from https://www.cdc.gov/rubella/pregnancy.html

Center for Disease Control and Prevention. (2019, March 28). MMR Vaccination What You Should Know Measles, Mumps, Rubella. Retrieved from https://www.cdc.gov/vaccines/vpd/mmr/public/index.html
Center for Disease Control and Prevention. (2020, February 3). Birth-18 Years Immunization Schedule. Retrieved from https://www.cdc.gov/vaccines/schedules/hcp/imz/child-adolescent.html#vaccines-schedule

Center for Disease Control and Prevention. (2020, March 20). Hepatitis B Questions and Answers for the Public. Retrieved from https://www.cdc.gov/hepatitis/hbv/bfaq.htm#overview

Center for Disease Control and Prevention. (2017, March). Vaccination coverage for selected diseases among children aged 19–35 months, by race, Hispanic origin, poverty level, and location of residence in metropolitan statistical area: United States, selected years 1998–2017. Retrieved from https://www.cdc.gov/nchs/data/hus/2018/031.pdf

Center for Disease Control and Prevention. (2018, December 31). Chickenpox. Retrieved from https://www.cdc.gov/chickenpox/surveillance/monitoring-varicella.html

Cockman, P., Dawson, L., Mathur, R., & Hull, S. (2011). Improving MMR vaccination rates: herd immunity is a realistic goal. Bmj, 343, d5703.

Conis E. (2011). "Do we really need hepatitis B on the second day of life?" vaccination mandates and shifting representations of hepatitis B. The Journal of medical humanities, 32(2), 155–166. https://doi.org/10.1007/s10912-010-9132-2

Craig, A. S., Watson, B., Zink, T. K., Davis, J. P., Yu, C., & Schaffner, W. (2007). Hepatitis A outbreak activity in the United States: responding to a vaccine-preventable disease. The American journal of the medical sciences, 334(3), 180-183.

Cuthbert J. A. (2001). Hepatitis A: old and new. Clinical microbiology reviews, 14(1), 38–58. https://doi.org/10.1128/CMR.14.1.38-58.2001

Dapaah-Siakwan, F., Gunasekaran, A., & Schutzman, D. L. (2016). C-reactive protein levels following hepatitis B vaccine in healthy newborns. Journal of Perinatology : Official Journal of the California Perinatal Association, 36(3), 231–234. https://doi-org.proxy.bsu.edu/10.1038/jp.2015.160

Dawson, L. (2004). The Salk Polio Vaccine Trial of 1954: risks, randomization and public involvement in research. Clinical Trials, 1(1), 122-130.

De Santis, M., Cavaliere, A. F., Straface, G., & Caruso, A. (2006). Rubella infection in pregnancy. Reproductive Toxicology, 21(4), 390-398.

Dunne, E. F., Unger, E. R., Sternberg, M., McQuillan, G., Swan, D. C., Patel, S. S., & Markowitz, L. E. (2007). Prevalence of HPV infection among females in the United States. Jama, 297(8), 813-819.

Fisher, L. M. (1986, October 13). Biotechnology Spotlight Now Shines on Chiron. *The New York Times*.

Gershon, A. A. (2006). Varicella-zoster virus. In Congenital and Perinatal Infections (pp. 91-100). Humana Press.

Greenberg, D., Givon-Lavi, N., Ben-Shimol, S., Ziv, J. B., & Dagan, R. (2015). Impact of PCV7/PCV13 introduction on community-acquired alveolar pneumonia in children< 5 years. Vaccine, 33(36), 4623-4629.

Haberling, D. L., Holman, R. C., Paddock, C. D., & Murphy, T. V. (2009). Infant and Maternal Risk Factors for Pertussis-Related Infant Mortality in the United States, 1999 to 2004. The Pediatric Infectious Disease Journal, 28(3), 194–198. doi: 10.1097/inf.0b013e31818c9032

Hadfield, T. L., Mcevoy, P., Polotsky, Y., Tzinserling, V. A., & Yakovlev, A. A. (2000). The Pathology of Diphtheria. The Journal of Infectious Diseases, 181(s1). doi: 10.1086/315551

Hagan, J. E., Wassilak, S. G., Craig, A. S., Tangermann, R. H., Diop, O. M., Burns, C. C., & Quddus, A. (2015). Progress toward polio eradication—worldwide, 2014–2015. MMWR. Morbidity and mortality weekly report, 64(19), 527.

Harrison, L. H., Trotter, C. L., & Ramsay, M. E. (2009). Global epidemiology of meningococcal disease. Vaccine, 27, B51-B63.

Howard, C., & Zuckerman, A.J. (1979). Hepatitis viruses of man. Boston: Academic Press. pp. 16–18.
JAMA. 191 (7): 541–6. doi:10.1001/jama.1965.03080070025007.

Jefferies, M., Rauff, B., Rashid, H., Lam, T., & Rafiq, S. (2018). Update on global epidemiology of viral hepatitis and preventive strategies. World journal of clinical cases, 6(13), 589–599. https://doi.org/10.12998/wjcc.v6.i13.589

Koepke, R., Eickhoff, J. C., Ayele, R. A., Petit, A. B., Schauer, S. L., Hopfensperger, D. J., ... & Davis, J. P. (2014). Estimating the effectiveness of tetanus-diphtheria-acellular pertussis vaccine (Tdap) for preventing pertussis: evidence of rapidly waning immunity and difference in effectiveness by Tdap brand. The Journal of infectious diseases, 210(6), 942-953.

Koprowski, H. (2011). History of Koprowski vaccine against poliomyelitis. In History of Vaccine Development (pp. 155-166). Springer, New York, NY.

Kyu, H. H., Mumford, J. E., Stanaway, J. D., Barber, R. M., Hancock, J. R., Vos, T., Murray, C. J., & Naghavi, M. (2017). Mortality from tetanus between 1990 and 2015: findings from the

global burden of disease study 2015. BMC public health, 17(1), 179. https://doi.org/10.1186/s12889-017-4111-4

Lapin, L.H. (1943). Whooping cough. 1st ed. Springfield, IL: Charles C Thomas. Lederle/Takeda Acellular Pertussis Component DTP (DTaP) Vaccine, the Lederle Whole-Cell Component DTP Vaccine, or DT Vaccine. Pediatrics, 101(1), 1–11. doi: 10.1542/peds.101.1.1

Mayo Clinic. (2017, October 27). Hepatitis B. Retrieved from https://www.mayoclinic.org/diseases-conditions/hepatitis-b/symptoms-causes/syc-20366802

McBEAN, A. M., Thoms, M. L., Albrecht, P., Cuthie, J. C., Bernier, R., & FIELD STAFF AND COORDINATING COMMITTEE. (1988). Serologic response to oral polio vaccine and enhanced-potency inactivated polio vaccines. American journal of epidemiology, 128(3), 615-628.

Meireles, L. C., Marinho, R. T., & Van Damme, P. (2015). Three decades of hepatitis B control with vaccination. *World journal of hepatology*, *7*(18), 2127–2132. https://doi.org/10.4254/wjh.v7.i18.2127

Miller, E., Andrews, N. J., Waight, P. A., Slack, M. P., & George, R. C. (2011). Effectiveness of the new serotypes in the 13-valent pneumococcal conjugate vaccine. Vaccine, 29(49), 9127-9131.

Mumps. (2019, March 15). Retrieved from https://www.cdc.gov/mumps/hcp.html#transmission

Naim H. Y. (2015). Measles virus. Human vaccines & immunotherapeutics, 11(1), 21–26. https://doi.org/10.4161/hv.34298

Noya, F., McCormack, D., Reynolds, D. L., Neame, D., & Oster, P. (1970). Safety and immunogenicity of two doses of quadrivalent meningococcal conjugate vaccine or one dose of meningococcal group C conjugate vaccine, both administered concomitantly with routine immunization to 12-to 18-month-old children. Canadian Journal of Infectious Diseases and Medical Microbiology, 25.

O'Ryan, M., Lucero, Y., & Linhares, A. C. (2011). Rotarix: vaccine performance 6 years postlicensure. Expert review of vaccines, 10(12), 1645-1659.

Obonyo, C. O., & Lau, J. (2006). Efficacy of Haemophilus influenzae type b vaccination of children: a meta-analysis. European Journal of Clinical Microbiology & Infectious Diseases, 25(2), 90–97. doi: 10.1007/s10096-006-0092-4

Ochmann S, Roser M. (2017). "Polio- Polio Cases (OWID based on US Public Health Service (1910-1951) and US Center for Disease Control (1960-2010))". ourworldindata.org.

Offit, P. A. (2007). The Cutter incident: how Americas first polio vaccine led to the growing vaccine crisis. New Haven, CT: Yale University Press.

Offit, P. A. (2008). *Vaccinated: one man's quest to defeat the world's deadliest diseases*. Washington, D.C.: Smithsonian Books.

Offit, P. A. (2015). *Deadly choices: how the anti-vaccine movement threatens us all*. New York: Basic Books, a member of the Persecus Book Group.

Oosterhuis-Kafeja, F., Beutels, P., & Van Damme, P. (2007). Immunogenicity, efficacy, safety and effectiveness of pneumococcal conjugate vaccines (1998–2006). Vaccine, 25(12), 2194-2212.

Oshinsky, D. M. (2005). Polio: an American story. Oxford University Press.
Parashar, U. D., Bresee, J. S., Gentsch, J. R., & Glass, R. I. (1998). Rotavirus. Emerging infectious diseases, 4(4), 561.

Parkman PD. Togaviruses: Rubella Virus. In: Baron S, editor. Medical Microbiology. 4th edition. Galveston (TX): University of Texas Medical Branch at Galveston; 1996. Chapter 55.

Pearce, J. M. S. (2004). Salk and Sabin: poliomyelitis immunization. Journal of Neurology, Neurosurgery & Psychiatry, 75(11), 1552-1552.
Pertussis Vaccination: Acellular Pertussis Vaccine for Reinforcing and Booster Use -- Supplementary ACIP Statement Recommendations of the Immunization Practices Advisory Committee. (1992). Retrieved from https://www.cdc.gov/mmwr/preview/mmwrhtml/00041801.htm

Pertussis Vaccination: Use of Acellular Pertussis Vaccines Among Infants and Young Children Recommendations of the Advisory Committee on Immunization Practices (ACIP). (1997). Retrieved from https://www.cdc.gov/mmwr//preview/mmwrhtml/00048610.htm

Petrosky, E., Bocchini Jr, J. A., Hariri, S., Chesson, H., Curtis, C. R., Saraiya, M., ... & Markowitz, L. E. (2015). Use of 9-valent human papillomavirus (HPV) vaccine: updated HPV vaccination recommendations of the advisory committee on immunization practices. MMWR. Morbidity and mortality weekly report, 64(11), 300.

Pilishvili, T., & Bennett, N. M. (2015). Pneumococcal disease prevention among adults: strategies for the use of pneumococcal vaccines. Vaccine, 33, D60-D65.

Rosenblatt, H. M., Song, L. Y., Nachman, S. A., Stanley, K. E., Krogstad, P. A., Johnson, G. M., & Wiznia, A. A. (2005). Tetanus immunity after diphtheria, tetanus toxoids, and acellular pertussis vaccination in children with clinically stable HIV infection. Journal of Allergy and Clinical Immunology, 116(3), 698–703. doi: 10.1016/j.jaci.2005.05.016

Schwartz, K. L., Kwong, J. C., Deeks, S. L., Campitelli, M. A., Jamieson, F. B., Marchand-Austin, A., Stukel, T. A., Rosella, L., Daneman, N., Bolotin, S., Drews, S. J., Rilkoff, H., & Crowcroft, N. S. (2016). Effectiveness of pertussis vaccination and duration of immunity. CMAJ

: Canadian Medical Association journal = journal de l'Association medicale canadienne, 188(16), E399–E406. https://doi.org/10.1503/cmaj.160193

Seward, J. F., Marin, M., & Vázquez, M. (2008). Varicella vaccine effectiveness in the US vaccination program: a review. The Journal of infectious diseases, 197(Supplement_2), S82-S89.

Smith, J. S., Gilbert, P. A., Melendy, A., Rana, R. K., & Pimenta, J. M. (2011). Age-Specific Prevalence of Human Papillomavirus Infection in Males: A Global Review. Journal of

Smith, J.S. (1991). *Patenting the Sun: Polio and the Salk Vaccine*. New York: Anchor/Doubleday.

Snape, M. D., Perrett, K. P., Ford, K. J., John, T. M., Pace, D., Yu, L. M., ... & Anemona, A. (2008). Immunogenicity of a tetravalent meningococcal glycoconjugate vaccine in infants: a randomized controlled trial. Jama, 299(2), 173-184.

Stehr, K., Cherry, J. D., Heininger, U., Schmitt-Grohé, S., Überall, M., Laussucq, S., … Christenson, P. (1998). A Comparative Efficacy Trial in Germany in Infants Who Received Either the

Stone, K. (1995). Human Papillomavirus Infection and Genital Warts: Update on Epidemiology and Treatment. Clinical Infectious Diseases., 20(Supplement_1), S91–S97. https://doi.org/10.1093/clinids/20.Supplement_1.S91

Thompson, K. M. (2013). Modeling poliovirus risks and the legacy of polio eradication. Risk Analysis, 33(4), 505-515.

Tsai, C. J., Griffin, M. R., Nuorti, J. P., & Grijalva, C. G. (2008). Changing epidemiology of pneumococcal meningitis after the introduction of pneumococcal conjugate vaccine in the United States. Clinical Infectious Diseases, 46(11), 1664-1672.

US Food and Drug Administration. (2010, July 14). Menveo. Retrieved from https://www.fda.gov/vaccines-blood-biologics/vaccines/menveo

US Food and Drug Administration. (2010, July 29). Menactra. Retrieved from https://www.fda.gov/vaccines-blood-biologics/vaccines/menactra

Van Herck, K., & Van Damme, P. (2005). Prevention of hepatitis A by Havrix™: a review. Expert review of vaccines, 4(4), 459-471.

Vesikari, T., Karvonen, A., Prymula, R., Schuster, V., Tejedor, J. C., Cohen, R., ... & Bouckenooghe, A. (2007). Efficacy of human rotavirus vaccine against rotavirus gastroenteritis during the first 2 years of life in European infants: randomised, double-blind controlled study. The Lancet, 370(9601), 1757-1763.

Viens, L. J., Henley, S. J., Watson, M., Markowitz, L. E., Thomas, C. C., Thompson, T. D., … Saraiya, M. (2016). Human Papillomavirus–Associated Cancers — United States, 2008–2012. MMWR. Morbidity and Mortality Weekly Report, 65(26), 661–666. doi: 10.15585/mmwr.mm6526a1

Von König, C. W., Halperin, S., Riffelmann, M., & Guiso, N. (2002). Pertussis of adults and infants. The Lancet infectious diseases, 2(12), 744-750.
von Mollendorf, C., Tempia, S., von Gottberg, A., Meiring, S., Quan, V., Feldman, C., Cloete, J., Madhi, S. A., O'Brien, K. L., Klugman, K. P., Whitney, C. G., & Cohen, C. (2017). Estimated severe pneumococcal disease cases and deaths before and after pneumococcal conjugate vaccine introduction in children younger than 5 years of age in South Africa. PloS one, 12(7), e0179905. https://doi.org/10.1371/journal.pone.0179905

Watt, J. P., Wolfson, L. J., Obrien, K. L., Henkle, E., Deloria-Knoll, M., Mccall, N., … Cherian, T. (2009). Burden of disease caused by Haemophilus influenzae type b in children younger than 5 years: global estimates. The Lancet, 374(9693), 903–911. doi: 10.1016/s0140-6736(09)61203-4

Worby, C. J., Kenyon, C., Lynfield, R., Lipsitch, M., & Goldstein, E. (2015). Examining the role of different age groups, and of vaccination during the 2012 Minnesota pertussis outbreak. Scientific reports, 5, 13182.

World Health Organization [WHO]. (2015, July 28). Polio eradication initiative. Retrieved from https://www.who.int/countries/eth/areas/immunization/pei/en/

World Health Organization [WHO]. (2016). "Polio vaccines: WHO position paper – March, 2016". Weekly Epidemiological Record. 91 (12): 145–68.

World Health Organization. (2014, April 30). Varicella. Retrieved from https://www.who.int/ith/diseases/varicella/en/

World Health Organization. (2014, January 24). Haemophilus influenzae type b (Hib). Retrieved from https://www.who.int/immunization/diseases/hib/en/

World Health Organization. (2018, February 19). Meningococcal meningitis. Retrieved from https://www.who.int/news-room/fact-sheets/detail/meningococcal-meningitis

World Health Organization. (2019, July 9). Hepatitis A. Retrieved from https://www.who.int/news-room/fact-sheets/detail/hepatitis-a

Zhao, Y.-L., Han, B.-H., Zhang, X.-J., Pan, L.-L., Zhou, H.-S., Gao, Z., Hao, Z.-Y., Wu, Z.-W., Ma, T.-L., Wang, F., Li, Q., Bi, S.-L., & Ma, J.-C. (2019). Immune persistence 17 to 20 years after primary vaccination with recombination hepatitis B vaccine (CHO) and the effect of booster dose vaccination. BMC Infectious Diseases, 19(1), 482.